Sensory Evaluation and Composition of Spaghetti Fortified with Soy Flour

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ABSTRACT: Spaghetti was prepared from durum wheat supplemented with soy flour in order to make an inexpensive, highly nutritious food and to determine the effects of high levels of soy flour on taste and textural attributes. Up to 50% soy flour was incorporated into spaghetti, resulting in a protein content of 33.5% (compared with 15.4% for control without soy) and a lysine content of 1.75% (compared with 0.41% for control). Sensory analysis of enriched spaghetti containing up to 35% soy flour indicated no significant difference in flavor and texture compared with control without soy, in general. Spaghetti with 50% soy flour had slightly higher beany and bitter flavors compared with control. This study showed that a high-protein and high-lysine spaghetti can be made with 35% soy flour without adverse effect on flavor and texture and should result in greater acceptability of soy-based foods.

Keywords: flavor, pasta, soy flour, texture, wheat flour

Introduction

Pasta is an inexpensive food usually made from wheat, which is consumed in most countries worldwide. It is, however, rather low in protein (<15%) and is relatively deficient in lysine, an essential amino acid. This is especially important for efforts to feed the hungry using pasta as the primary source of calories and protein. Pastas and breads made from low-protein grains make up a sizeable portion of diets among the undernourished in some countries in Africa and Asia. Even in the U.S., diets deficient in protein occur among the poor who sometimes depend on low-cost breads and pastas for nutrition.

Therefore, there have been many studies to supplement pasta with proteins rich in lysine, such as soy protein (Paulsen 1961; Clausi 1971; Siegel and others 1975; Laignelet and others 1976; Haber and others 1978; Buck and others 1987; Taha and others 1992; Collins and Pangloli 1997 Ugarcic-Hardi and others), fish protein concentrate (Kwee and others 1969; Sidwell and others 1970), legumes and their protein concentrates (Bahnassey and Khan 1986; Bahnassey and others 1986), corn distillers' dried grains (Wu and others 1987), and corn gluten meal (Wu and others 2001). Soy flour is attractive because it is abundant and inexpensive (approximately $0.20/lb) compared to animal proteins (>$1/lb) Corn gluten meal is even lower in cost ($0.13/lb), similar to wheat flour. Soy foods have been found to have beneficial effects in reducing risks of coronary heart disease and may reduce risks for some cancers (Messina 2003; Ohr 2004; Wietrzyk and others 2005).

Soy flours are known to often have unpleasant "beany" aromas and flavors, and this has limited the acceptability of soy-based foods in western societies (Rackis and others 1979). Some studies have shown that pastas with as little as 15% to 20% soy flour have significantly lower taste scores than the control pasta (Siegel and others 1975; Breen and others 1977; Taha and others 1992; Singh and others 2004), while others have indicated little change in overall flavor up to 25% soy flour (Collins and Pangloli 1997; Ugarcic-Hardi and others 2003). Similarly, flavor quality of pasta with 5% corn gluten meal was found to be lower than control (Wu and others 2001). Firmness of pasta has usually been found to increase with addition of soy flour (Paulsen 1961; Buck and others 1987; Taha and others 1992; Singh and others 2004). There have been no published studies on pastas containing >30% soy flour. In addition, previous sensory studies have only described overall flavor preference rather than individual flavor attributes, such as beany, wheat, and so on. The objective of this report was to investigate the preparation, composition, and detailed sensory analysis of pastas made from 0 to 50% soy flour and 0 to 5% corn gluten meal with a flavor-masking agent included with the corn meal gluten (CGM).

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Materials and Methods

Materials

Bakers NUTRISOY Flour (Archer Daniels Midland Co., Decatur, Ill., U.S.A.) was defatted soy flour that had been moderately heat-treated. Corn gluten meal was from Williams Co. (Pekin, Ill., U.S.A.), and the meal was ground to pass through a sieve with 246 μm square openings. MQ 71 masking agent (Virginia Dare, Brooklyn, N.Y., U.S.A.) also contained malto-dextrin, dietary fiber, and soy extract. Durum flour was from North Dakota Mill (Grand Forks, N. Dak., U.S.A.). Durum flour was hydrated to 31% moisture content and extruded into spaghetti using a DeMaco Laboratory extruder as described earlier (Wu and others 2001). Fortified spaghetti was prepared by replacing durum flour with defatted soy flour and corn gluten meal. Masking agent was added to spaghetti containing corn gluten meal at a level of 0.5 g per 100 g of flour. One hundred grams of sample was added to 2 L of boiling distilled water and allowed to cook for 10 min. Samples were drained and served.

Sensory analysis

Sensory analysis was performed at The Sensory Analysis Center, Kansas State Univ. (Manhattan, Kans., U.S.A.). Pastas were analyzed using a spectrum method, modified to use product-specific references, with general procedures similar to previous studies (Allison and others 2001). The panel consisted of 10 highly trained personnel

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(>120 h descriptive training, >2000 h testing experience). Panelists were selected on the basis of their ability to discriminate and scale a broad range of different attributes. Panel members were paid hourly. Panel orientation consisted of 3 h of product-specific attribute/definition development and the exploration of appropriate product references. Definitions and references are listed in Figure 1. Reference and product attribute scores were based on a 15-point scale with 0.5-point increments (1 = threshold, 1.5 to 5 = slight; 5.5 to 10 = moderate; 10.5 to 15 = strong.). Five samples were evaluated in 3 replicates during 2 d. Panelists were served approximately $\frac{1}{4}$ cup of sample for each evaluation in glass beakers warmed to 27 °C. Panelists evaluated texture attributes using a strand of spaghetti approximately 15-cm long. Samples were evaluated under green and red lights to mask color differences.

Chemical analyses

Moisture, crude protein, crude fat, crude fiber, and ash were determined in duplicate by Official Methods (AOAC 2000). Moisture was measured by loss in weight after heating in a vacuum oven, Nitrogen was determined by combustion analysis (LECO), and crude protein was calculated from nitrogen × 6.25. Crude fat was from ether extraction. Amino acid composition was measured in duplicate by Official Methods (AOAC 1995) after acid hydrolysis, performic acid oxidation followed by acid hydrolysis, and alkaline hydrolysis.

Statistical analyses

Data were fit to a GLM using SAS Version 8.0 and ANOVA, and LSD means comparison were used to determine if significant differences ($P < 0.05$) existed for descriptive sensory analysis. For proximate analysis and amino acid composition, means were compared by *t*-tests of pairs of least square means using $P < 0.05$ as significant difference.

Results and Discussion

Proximate composition

Table 1 shows the proximate composition of soy-fortified spaghetti. A large increase in protein content of spaghetti from 15% to 25% was observed when 25% defatted soy flour was substituted for durum flour. Additional substitution of 5% corn gluten meal for durum flour further increased protein content to 26%. Substitution of 35% soy flour for durum flour resulted in spaghetti with 30% protein, double the protein content of original spaghetti. Substitution of 50% soy flour for durum flour further increased the protein content of spaghetti. Ash content of spaghetti increased as soy flour replaced durum flour in spaghetti. Although there were statistical differences ($P < 0.05$) for crude fat and crude fiber contents of spaghetti, they were not of practical significance. These results are similar to those of previous studies (Molina and others 1982; Collins and Pangloli 1997) showing increases of protein, fiber, and ash content with increasing soy flour.

Amino acid composition

As shown in Table 2, spaghetti from 100% durum flour had 0.41 g lysine and 0.43 g threonine per 100 g sample or 2.67 g lysine and 2.77 g threonine per 100 g protein, and is deficient in lysine and threonine compared with the requirement of a 2- to 5-y-old child (World Health Organization 1985). Replacement of soy flour for durum flour increased lysine, threonine, and other amino acids of resulting spaghetti. Soy-fortified spaghetti is thus more nutritious than the regular spaghetti in supplying essential amino acids, in agreement with previous work (Laignelet and others 1976; Molina and others 1982).

Sensory analyses

Table 3 lists the mean intensity scores of spaghetti texture. There were no significant differences in firmness and cohesiveness of mass

TEXTURE:

Note: Texture attributes evaluated on 1 piece of pasta approximately 15 cm long.

Firmness: Force required to bite completely through sample on first bite with molars.
- **Reference:** Kraft Mild Cheddar Cheese = 4.0; Kroger Stuffed Olives = 8.0
- **Preparation:** Cut cheese into 1.3-cm cubes and put in a 96-mL soufflé cup, one for each panelist, 6-8 cubes per cup.

Cohesiveness of mass: Degree to which the mass holds together during mastication measured after 10 chews.
- **Reference:** Bar S Franks = 6.0; Kraft Mild Cheddar Cheese = 9.0; Reames Frozen Egg Noodles (thawed) = 10.0
- **Preparation:** Cook hot dogs according to package directions for stove top. Then slice into 1.3 cm pieces and place 3-5 piecesin a 96 ml soufflé cup for each panelist, Cut cheese into 1.3 cm cubes and put in a 96 ml soufflé cup, one for eachpanelist, 6-8 cubes per cup. Spread out frozen egg noodles on to a cookie sheet. Let set out until thawed, approximately 15 minutes. StoreOvernight in the refrigerator in 96 ml cups, covered.

Grainy: Perception of small irregular particles during mastication.
- **Reference:** Musselman's Apple Butter = 4.0; Malt O'Meal = 12.0
- **Preparation:** Prepare Malt O'Meal according to package directions for stove top.

Starchy mouthcoating: Degree to which sample mixes with saliva to form a starchy, pasty slurry that coats mouth surfaces during mastication.
- **Reference:** American Beauty Elbo-Roni = 8.0
- **Preparation:** Prepare according to package directions. Make fresh daily.

Figure 1—Pasta sensory definition and reference.

FLAVOR:

Grain: A general term used to describe the aromatics associated with grains such as corn, oats, and wheat. It is an overall grainy impression characterized as sweet, brown, sometimes generic nutty.
- **Reference:** American Beauty Elbo-Roni = 4.5.
  Wonder Bread "BIG" Slice = 5.0 (flavor)
  Kretschmer Wheat Germ = 7.5 (flavor)
- **Preparation:** Remove crust of bread and discard. Cut remaining bread into 2.5 cm squares and put into a 96 mL soufflé cup, one for each of the panelists, 6-8 pieces per cup.

Corn: Grain aromatics characteristic of corn.
- **Reference:** Quaker Yellow Corn Meal = 5.0 (flavor)
  Corn Gluten Meal = 5.0 (aroma)
  Orville Redenbacher's Original Corn (popped) = 8 (flavor)
- **Preparation:** Pop 1/2 cup popcorn in a West Bend Air Corn Popper.

Wheat: A light baked, wheat flour aromatic.
- **Reference:** Gold Medal All Purpose Flour = 5.0 (flavor)
- **Preparation:** Bake 1 cup of flour in a 23 x 33 cm glass-baking dish at 177 ˚ for 5 minutes. Stir and serve in soufflé cups, covered.

Beany: A slightly brown, musty, slightly nutty, starchy flavor associated with cooked dry beans. A green, vegetable aromatic characteristic of raw green beans or pea pods.
- **Reference:** Kroger Lima Beans (canned) = 4.5 (flavor)
- **Preparation:** Drain and rinse beans with cold water and place 1 tablespoon in 96 mL soufflé cup, cover.

Raw: An uncooked aromatic associated with grain products that are raw or uncooked.
- **Reference:** American Beauty Elbo-Roni = 8.0 (flavor)
- **Preparation:** Prepare according to package directions. Make fresh daily.

Fermented: Sweet, slightly brown, overripe aromatics associated with fermentedfruits, vegetables, or grains and it may have yeasty notes.
- **Reference:** Linalyl butyrate = (character reference)
  Wonder Bread "Big Slice" = 6.0 (aroma)
- **Preparation:** Remove crust of bread and discard. Cut remaining bread into 2.5 cm squares and put into a 96 mL soufflé cup, one for each of the panelists, 6-8 pieces per cup.

Bitter: The fundamental taste factor of which caffeine in water is typical.
- **Reference:** 0.01% Caffeine Solution = 2.0
  0.02% Caffeine Solution = 3.5
  0.035% Caffeine Solution = 5.0
  0.05% Caffeine Solution = 6.5

Figure 1—Continued

between the durum wheat control and soy fortified spaghetti up to 50% soy. This is somewhat surprising as other studies have shown that firmness of pasta, measured mechanically, increases with increasing level of soy flour (Buck and others 1987; Taha and others 1992; Singh and others 2004). Perhaps firmness is perceived by people during biting somewhat differently than the mechanical test. Another possibility here is that the processing history of the soy flour, particularly the heat treatment used to inactivate lipoxygenases, causes changes in the functional properties. Heat treatment histories were not provided for most of the previous studies noted above. It is known that heat treatment causes aggregation and insolubilization of soy proteins (Ribotta and others 2004). Such changes may also lead to different mechanical properties of extruded products but there do not seem to be many published studies in this area. There is also little data available on variability in functional properties of soy flours from lot to lot.

Spaghetti made from 25% soy + 70% durum + 5% corn gluten meal was found to have significantly higher grainy texture than spaghetti from 100% durum and from 25% soy + 75% durum. This was probably due to the persistence of the particulate form of the corn gluten meal in the cooked spaghetti. There was no significant difference in grainy texture between the soy-fortified and the control durum wheat spaghetti. Spaghetti from 50% soy + 50% durum was found to have a slightly higher starch mouthcoating than spaghetti from 100% durum. This suggests that the soy flour component may mix with saliva and form a pasty slurry in the mouth more readily than the durum wheat flour component.

Mean intensity flavor scores are shown in Table 4. No significant differences were found in wheat and raw flavor attributes for the five spaghetti samples. Spaghetti from 25% soy + 70% durum + 5% corn gluten meal had significantly higher grain and corn flavor than spaghetti from 100% durum. This was due to the intense corn flavor of the corn gluten meal. There were no significant differences in beany flavor between the control wheat and soy-enriched spaghetti up to 35% soy flour. Spaghetti from 50% soy + 50% durum had significantly higher beany flavor than spaghetti from 100% durum and from 25% soy + 75% durum. The beany flavor score of 1.4 for the 50% soy flour sample was still very low (near threshold), however. The particular soy flour used for this study and a recent study of soy flour/whole-wheat flour bread had only a moderate beany

Table 1—Proximate composition of soy-fortified spaghetti (% as-is)[a]

Sample	Moisture	Crude protein	Crude fat	Crude fiber	Ash
100% durum flour	9.74b	15.36f	0.21b	0.34d	1.04f
25% soy + 75% durum	9.85b	25.08e	0.13c	0.34d	2.38d
25% soy + 70% durum + 5% corn gluten meal	9.78b	26.43d	0.38a	0.55a	2.12e
35% soy + 65% durum	9.83b	30.47b	0.17bc	0.46b	3.21b
50% soy + 50% durum	10.09a	33.50a	0.15c	0.41c	3.67a

[a]Means in column followed by the same letter are not significantly different from one another ($P > 0.05$).

Table 2—Amino acid compositions of soy-fortified spaghetti (g/100 g sample)[a]

Amino acid	100% durum flour	25% soy + 75% durum	25% soy + 70% durum + 5% CGM	35% soy + 65% durum	50% soy + 50% durum
Aspartic	0.83e	2.01d	2.01d	2.79b	3.21a
Threonine	0.43f	0.79e	0.83d	1.02b	1.14a
Serine	0.62d	1.01c	1.08c	1.23b	1.34a
Glutamic	5.32e	6.32d	6.70c	7.05b	7.46a
Proline	1.66d	1.91c	2.09b	2.06b	2.09b
Glycine	0.51f	0.89e	0.91d	1.15b	1.28a
Alanine	0.49f	0.87e	1.09d	1.12c	1.25a
Cystine	0.36d	0.49c	0.50c	0.56b	0.58a
Valine	0.68f	1.10e	1.14d	1.37b	1.55a
Methionine	0.30e	0.38d	0.43c	0.46b	0.49a
Isoleucine	0.59e	0.99d	1.01d	1.27b	1.44a
Leucine	1.14d	1.81c	2.23b	2.24b	2.48a
Tyrosine	0.35e	0.68d	0.83c	0.89b	1.00a
Phenylalanine	0.79f	1.24e	1.35d	1.52b	1.68a
Histidine	0.39e	0.62d	0.63d	0.78b	0.90a
Lysine	0.41f	1.07d	1.01e	1.51b	1.75a
Arginine	0.66e	1.39d	1.39d	1.87b	2.14a
Tryptophan	0.19e	0.35d	0.34d	0.44b	0.47a

[a]Means in row followed by the same letter are not significantly different from one another ($P > 0.05$).

flavor (Shogren and others 2003). Beany flavors of soy flours can vary significantly with soy bean variety, handling, and processing (Ranhotra and Loewe 1974) and this may account for the variability of taste preferences reported in the literature for soy/wheat pastas (see Introduction). There was no significant difference in bitter flavor between the control wheat and soy-enriched spaghetti up to 35% soy flour, while bitter flavor was slightly higher with 50% soy flour (3.8) compared with the durum control (3.2). Both bitter and beany flavors have been associated with different chemicals produced by the lipoxygenase catalyzed oxidation of native lipids in soy beans (Rackis and others 1979).

Spaghetti from 25% soy + 70% durum + 5% corn gluten meal had significantly higher beany, fermented, and bitter flavors than spaghetti from 100% durum. This occurred despite the presence of the flavor-masking agent. The corn gluten meal probably acquires these off flavors due to its high unsaturated fat content and consequent ease of oxidation to rancid compounds (Buck and others 1987). Colors of the spaghetti samples were not evaluated by the panel but were slightly darker than the control.

Conclusions

Soy-fortified spaghetti made by substituting soy flour for up to 50% of the durum flour had greatly increased protein content and lysine content. There were no significant differences in textural and flavor characteristics between spaghetti made with all durum wheat and spaghetti with up to 35% soy flour. Even at the 50% soy flour level, differences from the control were rather small. Such differences might be difficult for an untrained person to distinguish and certainly further studies with a consumer panel would be warranted to study consumer preferences. These data suggest that pasta manufacturers should be able to incorporate selected soy flours into pastas at levels of at least 35%, much higher than the 20% level accepted in the past. Such inexpensive, high soy protein pastas should

Table 3—Mean intensity scores[a]—texture

Sample	Firmness	Cohesiveness of mass	Grainy	Starchy mouthcoating
100% durum flour	4.1	6.4	3.1bc	7.6b
25% soy + 75% durum	4.3	6.7	2.1c	8.5ab
25% soy + 70% durum + 5% corn gluten meal	4.3	7.6	8.0a	9.1ab
35% soy + 65% durum	4.3	7.4	5.8abc	8.8ab
50% soy + 50% durum	4.3	8.4	7.9ab	9.6a
LSD[b]	—	—	4.91	1.67

Means with the same letter within a column are not significantly different at the 95% confidence level.
[a]Means based on 15-point intensity scale with 0.5 point increments.
[b]LSD = least significant difference; the smallest difference between 2 means that would result in a significant difference at the 95% confidence level.

Table 4 — Mean intensity scores[a] — flavor

Sample	Grain	Corn	Wheat	Beany	Raw	Fermented	Bitter
100% durum flour	5.3b	1.0b	4.5	0.3c	8.3	0.1b	3.2b
25% soy + 75% durum	5.8ab	1.1b	4.7	0.5bc	8.6	0.3b	3.3ab
25% soy + 70% durum + 5% corn gluten meal	6.1a	3.8a	3.6	1.1ab	8.8	1.1a	3.7a
35% soy + 65% durum	5.9ab	1.8ab	4.4	0.9abc	8.8	0.4b	3.7ab
50% soy + 50% durum	6.0ab	3.2ab	3.9	1.4a	9.1	0.5ab	3.8a
LSD[b]	0.77	2.32	—	0.82	—	0.53	0.53

Means with the same letter within a column are not significantly different at the 95% confidence level.
[a]Means based on 15-point intensity scale with 0.5 point increments.
[b]LSD = least significant difference; the smallest difference between 2 means that would result in a significant difference at the 95% confidence level.

be valuable in feeding the hungry across the world as well as in promoting the health benefits of soy-based foods.

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